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[54] EXHAUST GAS RECIRCULATION SYSTEM WITH CONTROL APPARATUS FOR EXHAUST GAS FLOW CONTROL VALVE

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[51] **Int. Cl.**^{2} **F02M 25/06**

[52] **U.S. Cl.** .... **123/119 A**

[58] **Field of Search** .... 123/119 A

[56] **References Cited**

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[57] **ABSTRACT**

An exhaust gas recirculation system for an internal combustion engine comprises an exhaust gas flow control valve; a vacuum actuator for operation of the flow control valve; and a control apparatus which provides an output vacuum to be applied to the vacuum actuator which is an amplification of the venturi vacuum.

3 Claims, 2 Drawing Figures

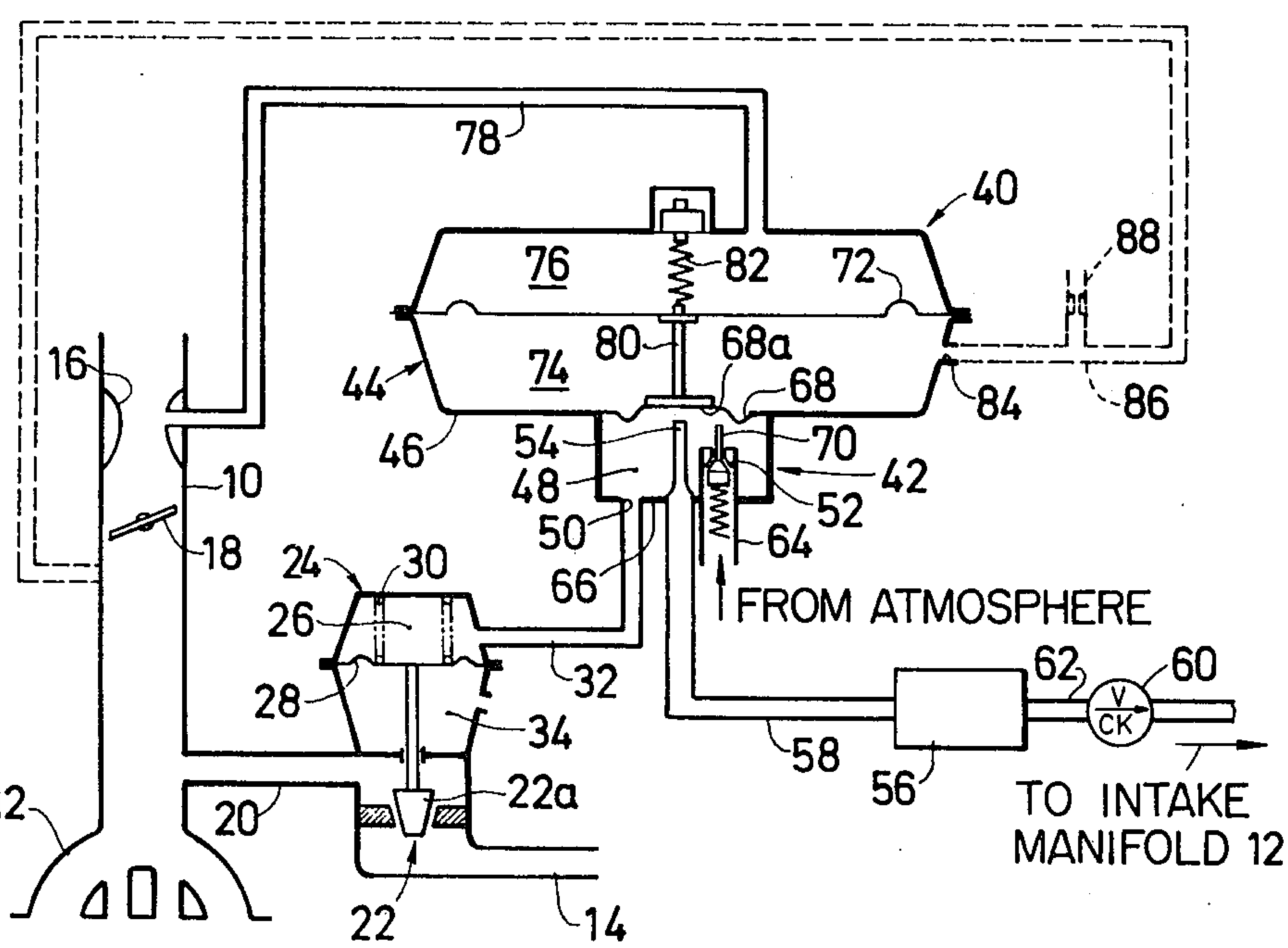

FIG. 1

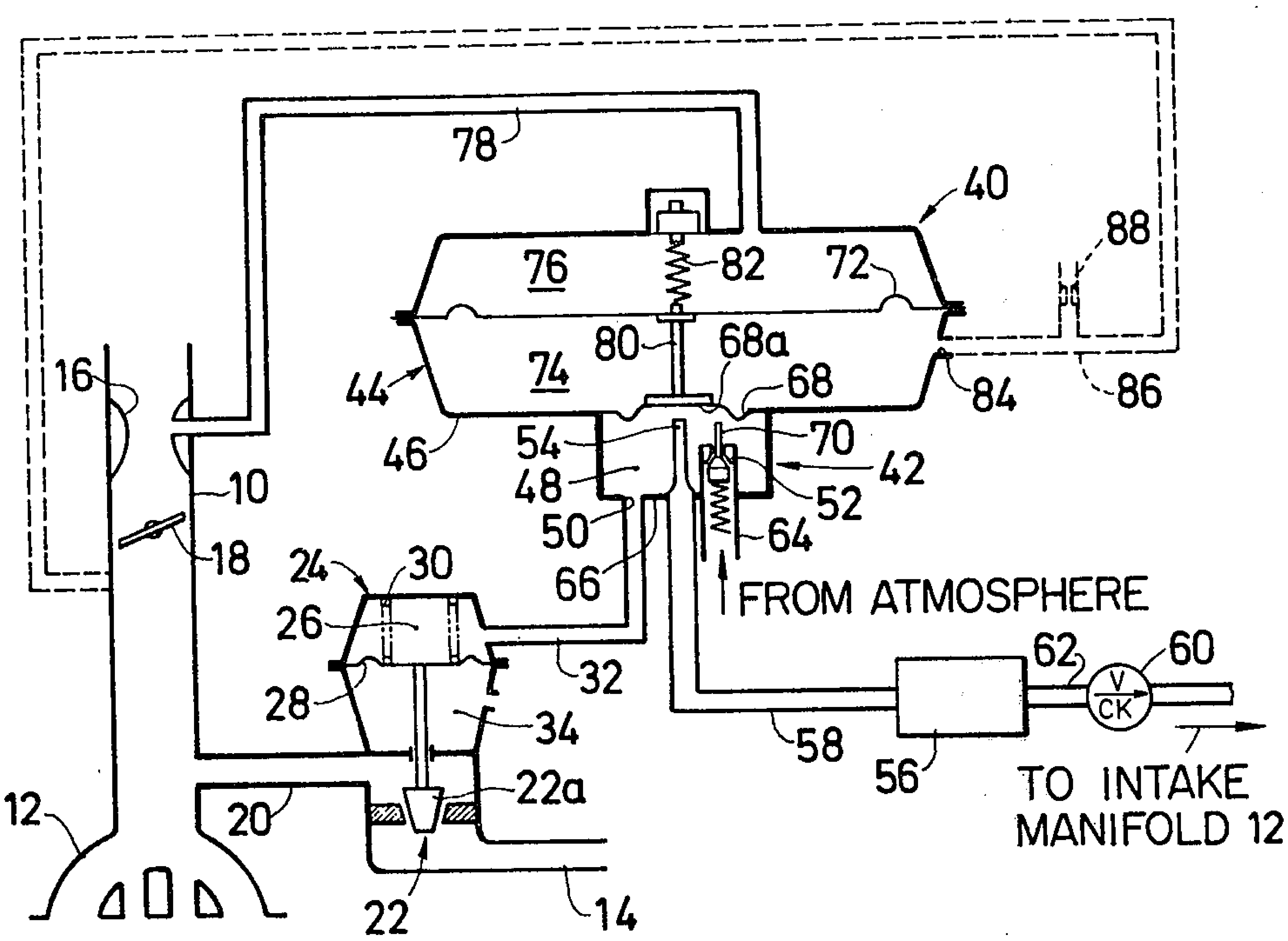
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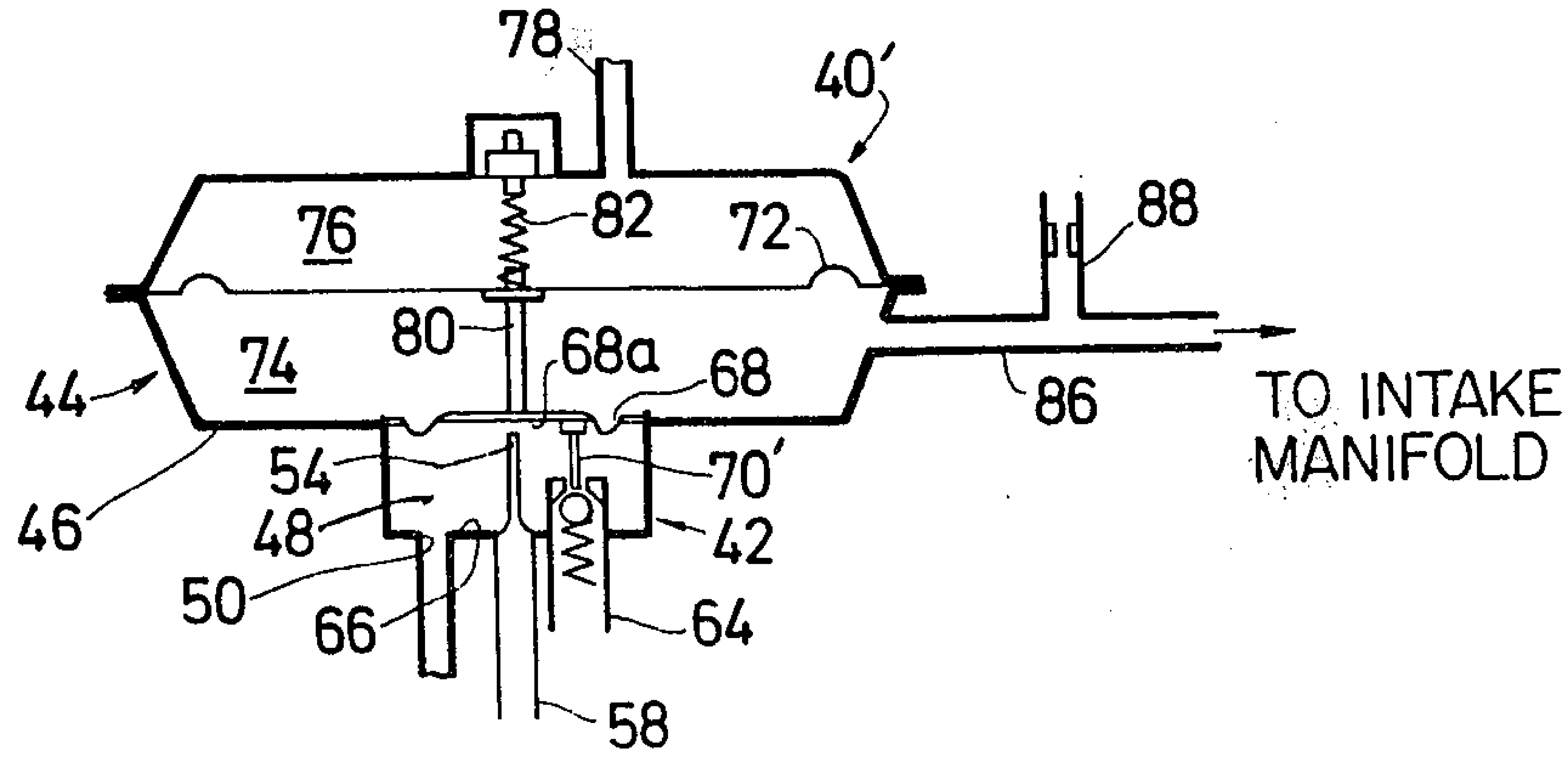
FIG. 2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EXHAUST GAS RECIRCULATION SYSTEM WITH CONTROL APPARATUS FOR EXHAUST GAS FLOW CONTROL VALVE

BACKGROUND OF THE INVENTION

The present invention relates to an exhaust gas recirculation system in an internal combustion engine, and more particularly to a control apparatus for an exhaust gas flow control valve of exhaust gas recirculation system.

Heretofore, there have been many proposals to introduce, throughout all operating conditions of an internal combustion engine, a substantially inert gas such as exhaust gas into the intake system; i.e. into the intake manifold or into the induction passage at a location downstream of the air filter; with the intention of reducing the concentration of nitrogen oxides (No_x) in the engine exhaust gases by suppressing their formation. It is required that a suitable amount of exhaust gas be introduced into the intake system of the engine to attain satisfactory results. A reduction in engine performance results if the ratio of the flow rate of recirculated exhausted gas to that of intake air exceeds a certain optimum value, and failure to suppress the formation of nitrogen oxides results if the ratio is much smaller than the certain optimum value. If intake manifold vacuum is employed to actuate a valve for controlling the flow of exhaust gas into the intake system of the engine, as is common in the prior art, it is hardly possible to maintain the flow rate ratio of recirculated exhaust gas to intake air at an optimum value mostly due to the fact that the vacuum in the intake manifold does not vary in proportion to the intake air flow rate throughout operation of the engine.

It has been confirmed that the vacuum in the venturi of a carburetor varies in relation to the velocity of air flowing through the venturi throughout operation of the engine, and therefore in relation to the flow rate of intake air being introduced into the engine. Thus, if the vacuum in the venturi is employed as a variable in controlling the amount of exhaust gas introduced into the intake system, the flow rate of exhaust gas can be metered to an optimum ratio to that of intake air throughout all modes of operation of the engine. However, the vacuum in the venturi is not strong enough for adequate control of a vacuum actuated valve to meter the flow rate of recirculated exhaust gas.

Conventionally, an exhaust gas recirculation system has a control apparatus providing a vacuum output which is an amplification of a vacuum in the venturi of a carburetor to a valve actuator of an exhaust gas flow control valve thereby to open an exhaust recirculation conduit responsive to changes in the venturi vacuum. When, in the conventional exhaust gas recirculation system, the intake manifold vacuum increases with the venturi vacuum remains unchanged, the flow rate ratio of recirculated exhaust gas to intake air increases above an optimum valve because flow rate of the exhaust gas through the recirculation conduit increases as the intake manifold increases even if the opening degree by the flow control valve is constant. Thus with the conventional exhaust gas recirculation system it is difficult to keep the flow rate of exhaust gas to an optimum ratio to that of intake air throughout all modes of operation of the engine. It is desirable that the opening degree of the flow control valve be decreased as the intake manifold vacuum increases or be increased as the intake manifold vacuum decreases so as to keep the flow rate ratio of recirculated exhaust gas to the venturi vacuum at an optimum value.

SUMMARY OF THE INVENTION

It is accordingly an object of the present invention to provide an exhaust gas recirculation system having a control apparatus which has a vacuum output which is an amplification of a vacuum in the venturi of a carburetor (the venturi vacuum) but modified by variation of a vacuum in the intake manifold vacuum (the intake manifold vacuum).

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become clear as this description progresses with reference to the accompanying drawings, in which:

FIG. 1 shows an exhaust gas recirculation system in accordance with the present invention; and

FIG. 2 shows a modification of a vacuum regulator used in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1 of the drawings, an exhaust gas recirculation system is shown as incorporated into an internal combustion engine which may be of any conventional design, being provided with a usual carburetor **10**, an intake manifold **12**, and exhaust pipe **14** leading from an exhaust manifold (not shown). The carburetor **10** is provided with a venturi section **16** and a throttle flap **18**.

The exhaust gas recirculation system includes an exhaust gas recirculation conduit **20** connecting the exhaust pipe **14** with the intake manifold **12** to recirculate a portion of the engine exhaust gas to the intake manifold **12**. An exhaust gas flow control valve **22** is mounted in the recirculation conduit **20**. The exhaust gas flow control valve **22** normally closes the recirculation conduit **20**. The valve **22** is urged toward its open position by a valve actuator **24**. The valve actuator **24** includes a vacuum chamber **26** and a flexible diaphragm **28** operatively connected to a valve member **22*a*** to urge the valve member **22*a*** against a compression spring **30** toward its opening position so as to open the recirculation conduit **20** responsive to a vacuum in the vacuum chamber **26**. The vacuum chamber **26** above the diaphragm **28** is connected by a vacuum conduit **32** to a control apparatus generally designated as **40**, whereas a chamber **34** beneath the diaphragm **28** is open to the atmosphere as shown.

The degree of vacuum present in the vacuum chamber **26** is controlled by the control apparatus **40** comprised of a vacuum regulator **42** and a vacuum motor **44** for actuating the regulator **42**. The vacuum regulator **42** and the vacuum motor **44** are ombined in a unitary structure.

The control apparatus **40** includes a housing **46** having a vacuum regulating chamber **48**. The vacuum regulating chamber **48** has an inlet port **50** connected to the vacuum chamber **26** through a vacuum conduit **32** for actuation of the diaphragm **28** by vacuum produced in the vacuum regulating chamber **48**. The regulating chamber has an air bleed port **52** and an outlet port **54** connected to a vacuum reservoir or source **56** by a vacuum pipe **58**, the vacuum reservoir **56** being connected to the engine intake manifold **12** through a check valve **60** and a vacuum pipe **62**.

The outlet port **54** is defined in the end portion of the vacuum pipe **58** projecting inwardly of the vacuum regulating chamber **48**, and the air bleed port **52** is defined in a boss **64** projecting inwardly of the vacuum regulating chamber **48**. The vacuum regulating chamber **48** is defined, on the side opposite wall **66**, by a flexible diaphragm means **68**. The flexible diaphragm means **68** has a valve portion **68*a*** engageable with the outlet port **54** and is movable in increases and decreases of pressure in the vacuum regulating chamber **48** to bring the portion **68*a*** into and out of closing engagement with the outlet port **54**. The boss **64** has an air bleeder valve **70** normally closing the air bleed port **52** under the influence of a spring but is opened by the diaphragm **68** upon further flexing downwardly of the diaphragm **68** due to increase of vacuum in the vacuum regulating chamber **48**.

The diaphragm **68** is actuated by the vacuum motor **44** comprising a flexible diaphragm **72**. The diaphragm **72** cooperates with the diaphragm **68** to form a biasing chamber **74** and its upper side is exposed to a venturi vacuum chamber **76** communicating with the venturi section **16** of the carburetor **10** by a vacuum conduit **78**. A rod **80** mechanically interconnects the two diaphragms **68** and **72**.

When the valve portion **68*a*** is raised by the diaphragm **68** to the illustrated position in which the air bleed port **52** is closed and the outlet port **54** is opened, the vacuum conduit **58** effects communication of the vacuum regulating chamber **48** with the vacuum reservoir **56**. When the valve portion **68*a***is lowered by the diaphragm **68**, the outlet port **54** is closed, and further lowering of the diaphragm **68** opens the air bleed port **52**. The reduction of the vacuum by this action tends to cause the diaphragm **68** to be moved upwardly, thereby sequentially closing the air bleed port **52** and then opening the outlet port **54**, thereby connecting the vacuum regulating chamber **48** with the vacuum reservoir **56**. An equilibrium is established whereby a vacuum of a predetermined value is produced in the vacuum regulating chamber **48** according to an upward force applied to the diaphragm **68**.

To provide a vacuum output in the vacuum regulating chamber **48** which is an amplification of the venturi vacuum in the venturi vacuum chamber **76** and acting on the upper side of the diaphragm **72**, an effective area of the diaphragm **72** is formed to be considerably larger than that of the diaphragm **68** and a tension spring **82** mechanically biases the diaphragm **72** upwardly.

The biasing chamber **74** has a vent port **84** opening to the atmosphere. Preferably the biasing chamber **74** is connected with the intake manifold **12** by means of a vacuum conduit shown in imaginary or broke lines and designated as **86**. The vacuum conduit **86** has an air bleeder orifice **88** having a restriction chosen such that a vacuum present in the biasing chamber **74** is a reduction of a vacuum in the intake manifold **12** and is considerably lower than a vacuum in the venturi vacuum chamber **76**. It will be understood that an upward force applied to the diaphragm **68** by the diaphragm **72** due to the venturi vacuum and by the spring **82** is reduced as the intake manifold vacuum increases, thereby causing a corresponding reduction of vacuum in the vacuum regulating chamber **48**. Thus it will now be appreciated that if the intake manifold vacuum increases with the venturi vacuum remained constant, the valve member **22*a*** of the flow control valve **22** is caused to decrease the opening degree of the recirculation conduit **20**.

In the control apparatus **40** illustrated in FIG. **1**, the air bleeder valve **70** includes a valve member integral with a stem which is spaced from the diaphragm **68**.

FIG. **2** shows a similar control apparatus **40'** to the control apparatus **40** shown in FIG. **1** and the same numerals to those used in FIG. **1** are used in FIG. **2** to designate like parts. Only difference resides in an air bleeder valve **70'**. The air bleeder valve **70'**includes a ball valve member normally closed by a spring and a separate stem secured to a valve portion **68*a***.

It will now be understood that the output vacuum in the vacuum regulating chamber **48** is an amplification of the venturi vacuum as far as the biasing chamber **74** is opened to the atmosphere or the reduced manifold vacuum induced in the biasing chamber **74** is substantially at constant level, but the output vacuum decreases as the reduced intake manifold increases or it increases as the reduced manifold vacuum decreases even if the venturi vacuum is at a constant level.

What is claimed is:

1. An exhaust gas recirculation system for use on an internal combustion engine having an intake system and an exhaust system comprising:

- a recirculation conduit to recirculate a portion of exhaust gas from the exhaust system of an internal combustion engine to an intake system having a carburetor and an intake manifold;
- an exhaust gas flow control valve normally closing said recirculation conduit;
- a valve actuator including a vacuum chamber and a diaphragm operatively connected to said exhaust gas flow control valve to urge said exhaust gas flow control valve toward its open position so as to open said recirculation conduit responsive to a vacuum in the vacuum chamber of said valve actuator; and
- a control apparatus comprising:
- a housing having a vacuum regulating chamber, said vacuum regulating chamber having an inlet port connected to the vacuum chamber of said valve actuator, an air bleed port and an outlet port connected in operation to a vacuum source;
- a first flexible diaphragm means defining a wall of said vacuum regulating chamber;
- a second flexible diaphragm means cooperating with said first flexible diaphragm means for defining said housing and between said first and second diaphragm means a biasing chamber, said second flexible diaphragm means forming on the opposite side of a side exposed to said biasing chamber and in said housing a venturi vacuum chamber communicating with the venturi of the carburetor;
- means mechanically interconnecting said first and second flexible diaphragm means;
- said first diaphragm means having a valve portion engageable with said outlet port, said first diaphragm means being movable in increase and decrease of pressure in said vacuum regulating chamber to bring said valve portion into out of closing engagement with said outlet port;
- said second diaphragm means having an effective area larger than that of said first diaphragm means;
- an air bleeder valve means for opening said air bleed port in response to further flexing of said first diaphragm means due to increase of vacuum in said vacuum regulating chamber after closing of said outlet port;
- a vacuum conduit having an air bleeder orifice, said vacuum conduit connecting said biasing chamber

with the intake manifold, and said air bleeder orifice having a restriction chosen such that a vacuum in said biasing chamber is a reduction of a vacuum in the intake manifold and is lower than a vacuum in said venturi vacuum chamber.

2. An exhaust gas recirculation system as claimed in

claim 1, in which said air bleeder valve means comprises a tapered conical valve element.

3. An exhaust gas recirculation system as claimed in claim 1, in which said air bleeder valve means comprises a ball valve element.

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